* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to the instruction preparation method which lessens delay of a servo, and degradation of the accuracy by vibration extremely in the control method of the positioning control system of an industrial robot, a machine tool, etc.
[0002]
[Description of the Prior Art]When positioning control of an industrial robot or a machine tool was performed, section accelerating with a positive certain acceleration value and acceleration had usually given the speed command of the trapezoidal shape constituted from the section of the constant speed of 0, and section decelerating with a negative certain acceleration value to the control device. In the positioning operation of a short distance like short pitch work, it becomes a speed command of the shape of a triangle which does not have the constant speed section as shown in drawing 5. Thus, in the response to such instructions, although the waveform of the acceleration commands at the time of expressing the acceleration and deceleration of speed with a primary function serves as rectangular wave shape, as shown in drawing 6, flattery delay arises. The flattery delay in a response causes an orbital gap of a load-axis tip, as shown in drawing 7.
[0003]In [in order to reduce response flattery delay, as it is shown in drawing 10] the feedforward control section 15, Although feed-forward control which adds what multiplied by the gain the feedforward speed command which differentiated the first degree of the position instruction, and the feedforward acceleration commands differentiated the second degree is performed, there is a problem that it is accompanied by overshooting as shown in drawing 8 in the response in this case. This overshooting is set to one of the causes of vibration produced at the load-axis tip as shown in drawing 9. There is a method of inputting instructions into a low pass filter, or asking for a moving average as a device for decreasing vibration of the load-axis tip in a vehicle zone. However, in the method which used the low pass filter and the moving average after such acceleration-and-deceleration processing, there is a problem that the flattery delay at the tip of a load axis arises by the

response delay of a lagged effect with a filter or a servo system.

[0004]In drawing 10, 11 a position control part and 12 a speed control part and 13 A motor section, 14 is a mechanism part, 15 is a feedforward control section, and K_p A position loop gain, A speed feedforward gain and K_{af} K_{vf} An acceleration feedforward gain, K_v -- a speed loop gain and J_m -- the moment of inertia of a motor, and K_t -- as for load side moment of inertia and D_m, a moderating ratio and K_c are [an integration gain and N / the load rate of reduction gears, and J_l / reduction-gears coefficient of viscosity and D_l of motor coefficient of viscosity and D_c] load side coefficient of viscosity. As for the angle of rotation of a motor, and θ'_m, a position instruction and u_{ref} are [θ_{mref} / acceleration commands and θ_m / the angle of torsion between a motor shaft and load and θ_l of the angular rate of rotation of a motor and θ_s] the angles of rotation of load. Thus, when acceleration commands are expressed with a square wave, the vibration suppression and response flattery nature at the tip of a load axis serve as a conflicting requirement. In order to solve these problems, the method of computing position instruction θ_{mref} whose reference positional function θ_{lref} corresponds with controlled-variable θ_l in consideration of the inverse transfer function of a controlled object which was indicated by JP,5-143106,A is proposed.

[0005]

[Problem(s) to be Solved by the Invention]However, in the method indicated by above-mentioned JP,5-143106,A, When the degree of reference positional function θ_{lref} is set up lower than the degree of the numerator polynomial showing the relation of position instruction θ_{mref}[of a control system / from output θ_l] of an inverse transfer function, In order that the function from which the value is set to 0 may come out into reference positional function θ_{lref} which constitutes θ_{mref} in a position instruction, and its differential coefficient, it becomes impossible to compute position instruction θ_{mref} whose reference positional function θ_{lref} corresponds with a controlled variable. Even if it sets up reference positional function θ_{lref} higher order than the denominator polynomial of the transfer function of the whole control system, Since a step function is included in position instruction θ_{mref} when the function which has an absolute term in reference positional function θ_{lref} which constitutes θ_{mref} in a position instruction, and its differential coefficient exists, There is a problem of being easy to produce vibration of a load-axis tip in a rigid low controlled object like an industrial robot. Then, also in the positioning control system of rigid low controlled objects, such as an industrial robot, there is the issue which this invention tends to solve in providing the instruction preparation method of the positioning control system which controls vibration produced at the tip of a load axis while canceling the flattery delay at the tip of a load axis.

[0006]

[Means for Solving the Problem]In an instruction preparation method of a positioning control system which this invention interpolates a position in the next teaching point from a certain taught point, and creates position instruction theta$_{mref}$ for every control cycle of a servo motor of each axis in order to solve an aforementioned problem, When a denominator polynomial showing a relation to position instruction theta$_{mref[\text{ of a control system / from output theta}_{l}]}$ of an inverse transfer function is a constant, In order to compute position instruction theta$_{mref}$ reference positional function theta$_{lref}$ at the tip of a load axis of each axis and whose output theta$_{l}$ of a control system correspond, In an instruction generation part, at least primary is higher order than a degree of a numerator polynomial of said inverse transfer function in reference positional function theta$_{lref}$, and it sets up so that said reference positional function theta$_{lref}$ which constitutes position instruction theta$_{mref}$, and its differential coefficient may not have an absolute term. When a denominator polynomial of an inverse transfer function is the primary more than polynomial, in order to compute position instruction theta$_{mref}$ reference positional function theta$_{lref}$ at the tip of a load axis of each axis and whose output theta$_{l}$ of a control system correspond, In an instruction generation part, the 1st [at least] order sets up said reference positional function theta$_{lref}$ high order from a degree of a numerator polynomial of an inverse transfer function, and a filter of a transfer function equivalent to a denominator polynomial of an inverse transfer function is formed. By doing in this way, position instruction theta$_{mref}$ reference positional function theta$_{lref}$ and whose output theta$_{l}$ of a control system correspond is computable.

[0007]

[Embodiment of the Invention]It explains referring to the position control system which shows drawing 1 the example of this invention hereafter. As for a position control part and 3, in drawing 1, 1 is [a motor section and 5] mechanism parts a speed control part and 4 an instruction generation part and 2. As for K_p, a speed loop gain and J_m a position loop gain and K_v The moment of inertia of a motor, K_t -- as for load side moment of inertia and D_m, a moderating ratio and K_c are [an integration gain and N / the load rate of reduction gears, and J_l / reduction-gears coefficient of viscosity and D_l of motor coefficient of viscosity and D_c] load side coefficient of viscosity. As for the angle of rotation of a motor, and theta'$_{m}$, a position instruction and u_{ref} are [theta$_{mref}$ / acceleration commands and theta$_{m}$ / the angle of torsion between a motor shaft and load and theta$_{l}$ of the angular rate of rotation of a motor and theta$_{s}$] the angles of rotation of load. In the instruction generation part 1, position instruction theta$_{mref}$ adds [coefficient a_0, a_1, a_2, a_3, a_4, and / a_5] to each from reference angle-of-rotation theta$_{lref}$ of load to the fifth floor differential value of the, applying them, and is generated by them through the filter 6.

[0008]Control input u_{ref} to the controlled object in drawing 1 becomes like several 1.

[Equation 1]

$$u_{ref} = Kv\left\{Kp\left(\theta_{mref} - \theta_m\right) - \theta_m'\right\} + Ki\int Kv\left\{Kp\left(\theta_{mref} - \theta_m\right) - \theta_m'\right\}dt$$

At this time, in the control system of drawing 1, position instruction theta$_{mref}$ with which reference positional function theta$_{lref}$ of control-output theta$_l$ corresponds can be computed from drawing 1 and several 1, and can be expressed with an inverse transfer function like several 2.

[Equation 2]

$$\theta mref = \frac{a_5 s^5 + a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s^1 + a_0}{b_2 s^2 + b_1 s^1 + b_0}\theta lref$$

$$a_0 = N^2 KpKvKiJmKc$$

$$a_1 = N^2 KvJm\left(KiKc + KpKi(Dc + Dl) + KpKc\right)$$

$$a_2 = N^2 Kv\left(KiJm(Dc + Dl) + KpKiJmJl + JmKc + KpJmKc(Dc + Dl)\right) + N^2 DmKc + KcDl$$

$$a_3 = N^2\left(KvKiJmJl + JmKc + Dm(Dc + Dl) + KvJm(Dc + Dl) + KpKvJmJl\right) + KcDcJmDl$$

$$a_4 = N^2\left(KvJmJl + JlDm + Jm(Dc + Dl)\right) + JlDc$$

$$a_5 = N^2 JmJl$$

$$b_0 = NKpKvKiJmKc$$

$$b_1 = NKpKvJm\left(Kc + KiDc\right)$$

$$b_2 = NKpKvJmDc$$

In order to generate position instruction theta$_{mref}$ in the control system of drawing 1 from several two, since the degree of the numerator polynomial of an inverse transfer function is the 5th order, reference positional function theta$_{lref}$ is set more than as the 6th polynomial, and the secondary filter 6 equivalent to several 2 denominator polynomial is set up.

[0009]Here, a case where there is no time of constant speed like short pitch operation is mentioned as an example. When acceleration function theta"$_{lref}$ expressed with drawing 2 and eight following formulas like several 3 is considered, reference positional function theta$_{lref}$ becomes like several 5 in a differential coefficient of reference positional function theta$_{lref}$ of several 4 others.

[Equation 3]

$$\theta_{lref}''(t) = \alpha \cdot t^4 (t - To)^4 \qquad 0 \le t \le To$$

$$\theta_{lref}''(t) = -\alpha \cdot (t - To)^4 \cdot (t - 2To)^4 \qquad To < t \le 2To$$

[Equation 4]

$$\theta_{lref}(t) = \alpha \cdot \left(\frac{t^{10}}{90} - \frac{To \cdot t^9}{9} + \frac{3 \cdot To^2 \cdot t^8}{7} - \frac{16 \cdot To \cdot t^7}{21} + \frac{8 \cdot To^4 \cdot t^6}{15} \right) \quad 0 \le t \le To$$

$$\theta_{lref}(t) = \alpha \cdot \left(\frac{(t-To)^{10}}{90} - \frac{To \cdot (t-To)^9}{9} + \frac{3 \cdot To^2 \cdot (t-To)^8}{7} - \frac{16 \cdot To \cdot (t-To)^7}{21} + \frac{8 \cdot To^4 \cdot (t-To)^6}{15} \right)$$

$$\mathrm{To} < t \le 2To$$

[Equation 5]

$$\theta'_{lref}(t) = \alpha \cdot \left(\frac{t^9}{9} - To \cdot t^8 + \frac{24 \cdot To^2 \cdot t^7}{7} - \frac{16 \cdot To \cdot t^6}{3} + \frac{16 \cdot To^4 \cdot t^5}{5} \right) \quad 0 \le \mathrm{t} \le \mathrm{To}$$

$$\theta'_{lref}(t) = \alpha \cdot \left(\frac{(t-To)^9}{9} - To \cdot (t-To)^8 + \frac{24 \cdot To^2 \cdot (t-To)^7}{7} - \frac{16 \cdot To \cdot (t-To)^6}{3} + \frac{16 \cdot To^4 \cdot (t-To)^5}{5} \right)$$

$$\mathrm{To} < \mathrm{t} \le 2\mathrm{To}$$

$$\theta'''_{lref}(t) = \alpha \cdot \left(8 \cdot t^7 - 56 \cdot To \cdot t^6 + 144 \cdot To^2 \cdot t^5 - 160 \cdot To^3 \cdot t^4 + 64 \cdot To^4 \cdot t^3 \right) \quad 0 \le \mathrm{t} \le \mathrm{To}$$

$$\theta'''_{lref}(t) = \alpha \cdot \left(8 \cdot (t-To)^7 - 56 \cdot To \cdot (t-To)^6 + 144 \cdot To^2 \cdot (t-To)^5 - 160 \cdot To^3 \cdot (t-To)^4 + 64 \cdot To^4 \cdot (t-To)^3 \right)$$

$$\mathrm{To} < \mathrm{t} \le 2\mathrm{To}$$

$$\theta^{(4)}{}_{lref}(t) = \alpha \cdot \left(56t^6 - 336 \cdot To \cdot t^5 + 720 \cdot To^2 \cdot t^4 - 640 \cdot To^3 \cdot t^3 + 192 \cdot To^4 \cdot t^2 \right) \quad 0 \le \mathrm{t} \le \mathrm{To}$$

$$\theta^{(4)}{}_{lref}(t) = \alpha \cdot \left(56(t-To)^6 - 336 \cdot To \cdot (t-To)^5 + 720 \cdot To^2 \cdot (t-To)^4 - 640 \cdot To^3 \cdot (t-To)^3 + 192 \cdot To^4 \cdot (t-To)^2 \right)$$

$$\mathrm{To} < \mathrm{t} \le 2\mathrm{To}$$

$$\theta^{(5)}{}_{lref}(t) = \alpha \cdot \left(336t^5 - 1680 \cdot To \cdot t^4 + 2880 \cdot To^2 \cdot t^3 - 1920 \cdot To^3 \cdot t^2 + 384 \cdot To^4 \cdot t \right) \quad 0 \le \mathrm{t} \le \mathrm{To}$$

$$\theta^{(5)}{}_{lref}(t) = \alpha \cdot \left(336(t-To)^5 - 1680 \cdot To \cdot (t-To)^4 + 2880 \cdot To^2 \cdot (t-To)^3 - 1920 \cdot To^3 \cdot (t-To)^2 + 384 \cdot To^4 \cdot (t-To) \right)$$

$$\mathrm{To} < \mathrm{t} \le 2\mathrm{To}$$

[0010]Position instruction theta$_{mref}$ is computed by substituting each of these elements for several 2, and position output theta$_l$ when this theta$_{mref}$ is inputted into the positioning control system shown in drawing 1 is shown in drawing 4. Position output theta$_l$ when position output theta$_l$ when position position instruction theta$_{mref}$ corresponding to the speed command of the shape of a conventional chopping sea as shown in drawing 5 for comparison was inputted into the control system of drawing 1 is inputted into drawing 7 at the control system using the feed-forward control shown in drawing 10 is shown in drawing 9. A time lag becomes it is few and possible [obtaining the response by which vibration was also pressed down] by this invention so that drawing 4, drawing 7, and drawing 9 may show. Since there are few gaps with a position instruction response and a desired position locus, when performing position control by a multiple spindle, the accuracy of an industrial robot, a machine tool of the locus by the side of a load axis also improves.

[0011]

[Effect of the Invention]As mentioned above, when the denominator polynomial showing the relation to position instruction

θ_{mref}[of a control system / from output θ_{l}] of an inverse transfer function is a constant according to this invention, In order to compute position instruction θ_{mref} reference positional function θ_{lref} at the tip of a load axis of each axis and whose output θ_{l} of a control system correspond, In an instruction generation part, at least primary is higher order than the degree of the numerator polynomial of said inverse transfer function in reference positional function θ_{lref}, And it sets up so that said reference positional function θ_{lref} which constitutes position instruction θ_{mref}, and its differential coefficient may not have an absolute term, When the denominator polynomial of an inverse transfer function is the primary more than polynomial, in order to compute position instruction θ_{mref} reference positional function θ_{lref} at the tip of a load axis of each axis and whose output θ_{l} of a control system correspond, By setting up said reference positional function θ_{lref} in an instruction generation part higher order [the 1st / at least / order] than the degree of the numerator polynomial of an inverse transfer function, and forming the filter of the transfer function equivalent to the denominator polynomial of an inverse transfer function, Position instruction θ_{mref} reference positional function θ_{lref} and whose output θ_{l} of a control system correspond is computable. Since the gap with a position instruction response and a desired position locus decreases as the result, improvement in the accuracy of position in a positioning control system can be aimed at.

[Translation done.]